Thermal Materials Workshop 2001

Application of Foam Metal Technology to Aircraft Systems- Direction and Status

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NORTHROP GRUMMAN

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14. ABSTRACT
? Outgrowth of DARPA Ultra-Lightweight Metallic Structures Program ? GASAR Component Design, Production, Test, and Cost-benefit Study (our introduction to this community) ? MURI (foams and periodic structures) ? Present Project ? Structurally Integrated Thermal Management of Airborne Early Warning & Electronic Warfare Systems ? Technology Transition ? DARPA Synthetic Multi-Functional Materials ? Rules and Tools, Relevant Database ? E-2C, Other Applications

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Program Participants

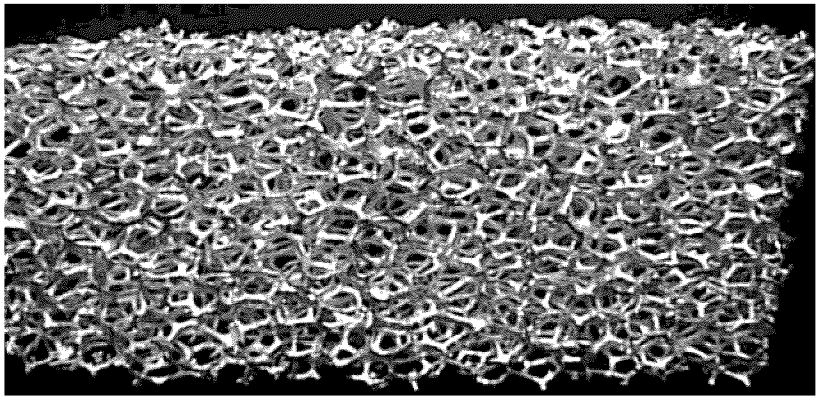
- Northrop-Grumman Corporation
  - Technology Development, AEW&EW systems business area
  - Logicon
- ONR / DARPA
- Ozer Engineering
- ERG

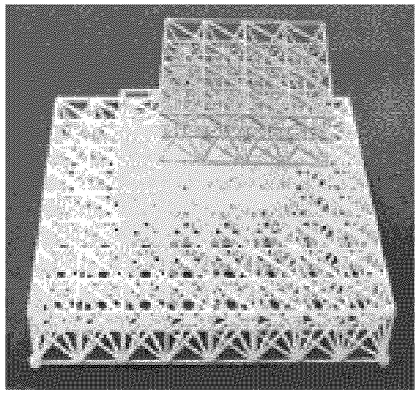
Introduction

- Outgrowth of DARPA Ultra-Lightweight Metallic Structures Program
  - GASAR Component Design, Production, Test, and Cost-benefit Study (our introduction to this community)
  - MURI (foams and periodic structures)
- Present Project
  - Structurally Integrated Thermal Management of Airborne Early Warning & Electronic Warfare Systems
  - Technology Transition
  - DARPA Synthetic Multi-Functional Materials
  - Rules and Tools, Relevant Database
  - E-2C, Other Applications

Technical Areas

- **Generic Technologies - Thermal and Structural Behavior of Metal Foams and Lattice Structures**



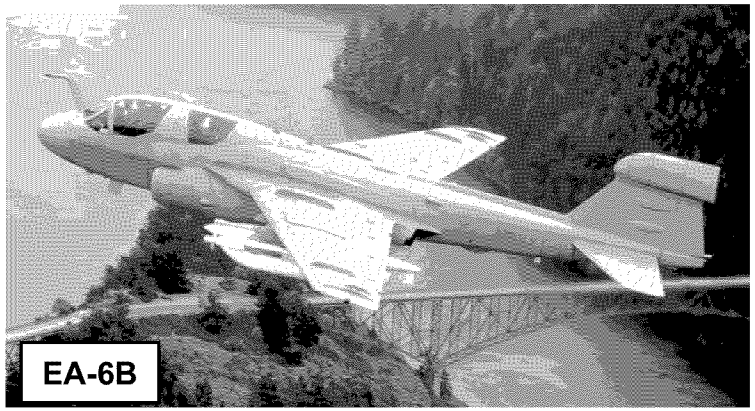


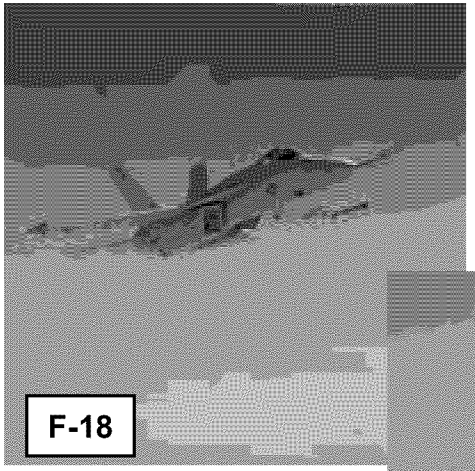
- **Specific Applications - Thermal Management for Airborne Early Warning & Electronic Warfare Systems**

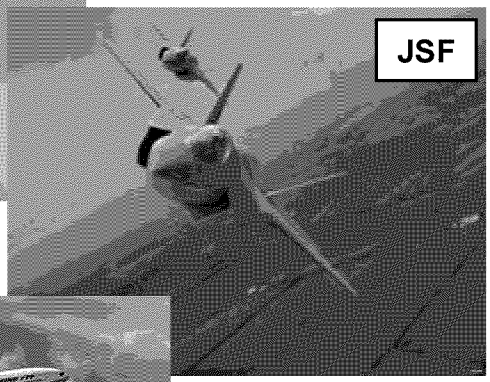
Applications

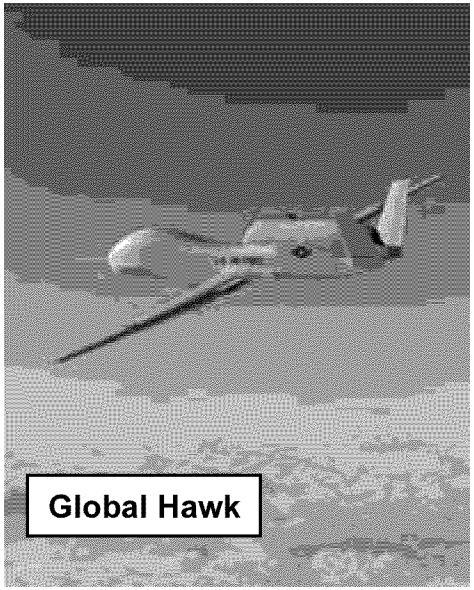
- E-2C Heat Exchanger Cores
- E-2C Avionics Racks
- EA-6B, F/A-18E/F, F/A-18G, JSF
- Unmanned Air Vehicles
- Commercial

High Efficiency Porous Metal Heat Exchangers









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Integrated Systems Sector

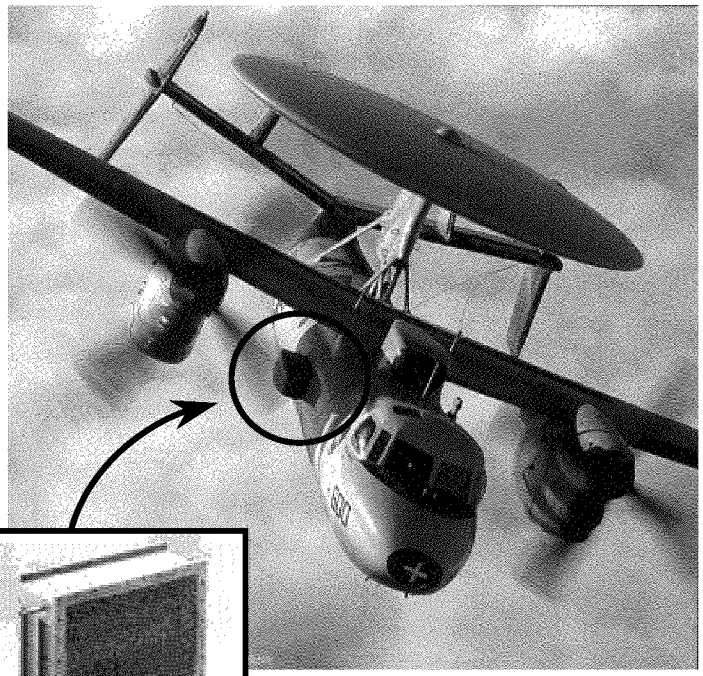
Project Tasks

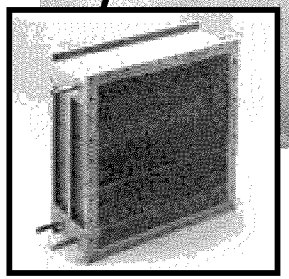
- 1a. E-2C LCS Heat Exchanger Element - Design, Fabrication and Test
- 2a. Heat Exchanger Elements for E-2C Avionics Racks – Concepts

E-2C Air/Liquid Heat Exchanger

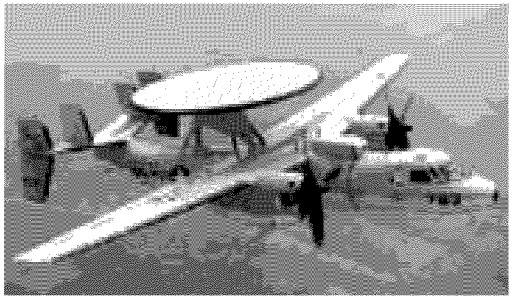
- Conventional Redesign of Air/Liquid Heat Exchanger to Accommodate Increased Load Plus Growth Large and Heavy
- Porous Metal Heat Exchanger Offers the Potential to be:
  - Lighter
  - Smaller
  - Less Expensive

  Than Conventional Redesign





Foam Metal
Heat Exchanger



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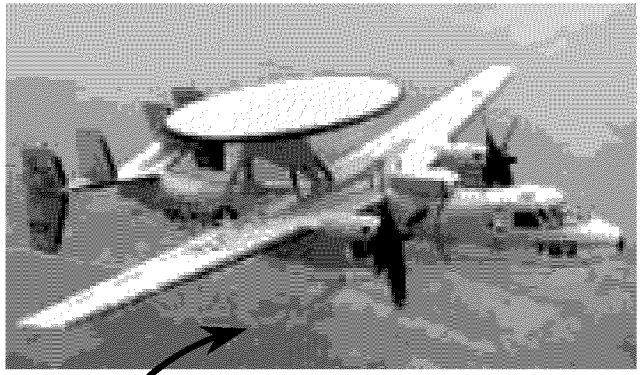
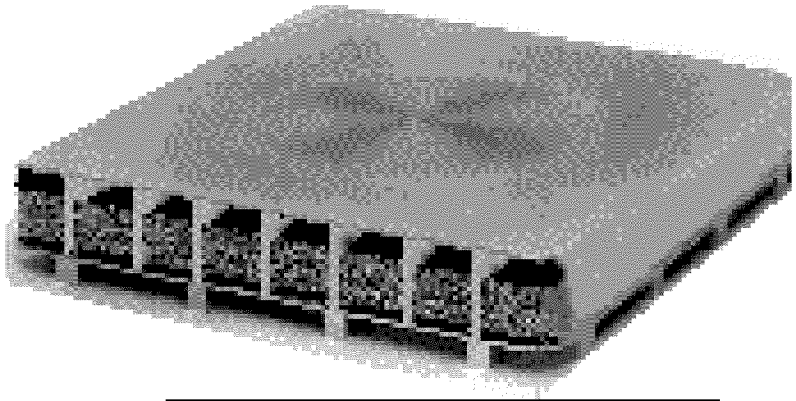
E-2C Integrated Avionics Rack

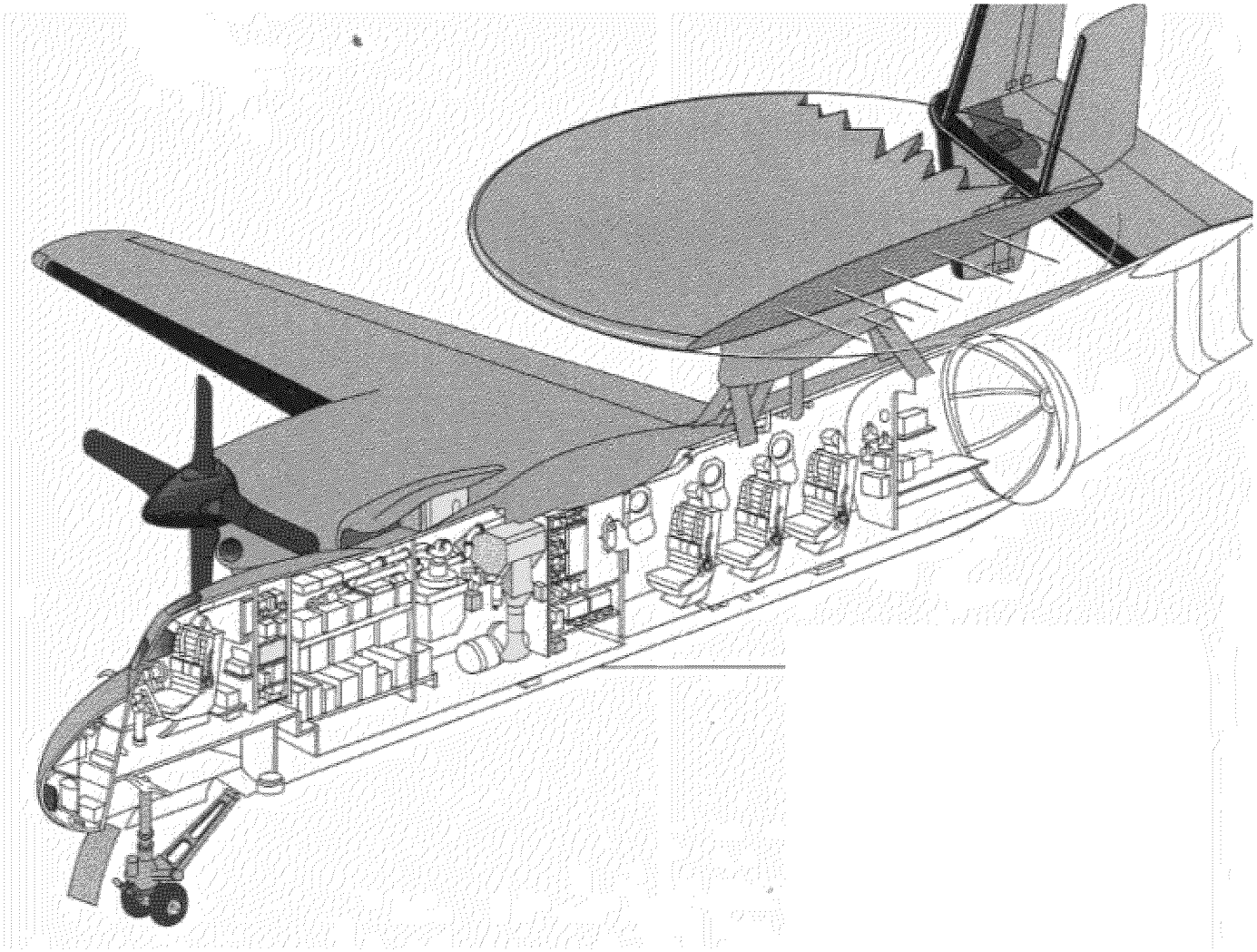




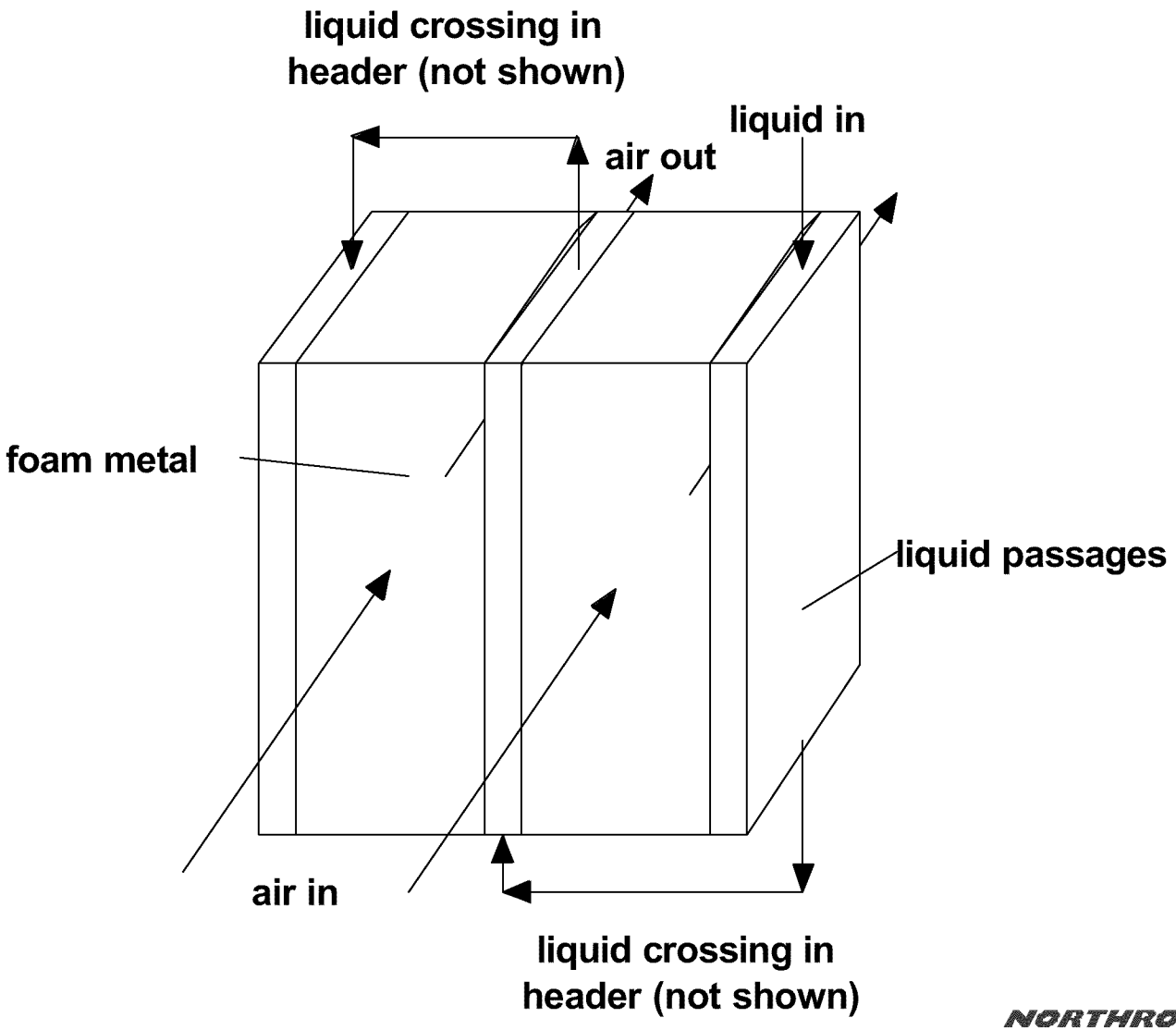
Integrated Avionics Rack

- New Avionics Suite and Redesign of Racks and Cards and Allow for an Integrated Approach to System Cooling
- Opportunity to Address Thermal Management by Incorporating Integrated Cooling Capability
- Integrated Racks Offer Weight, Performance, Size Advantages

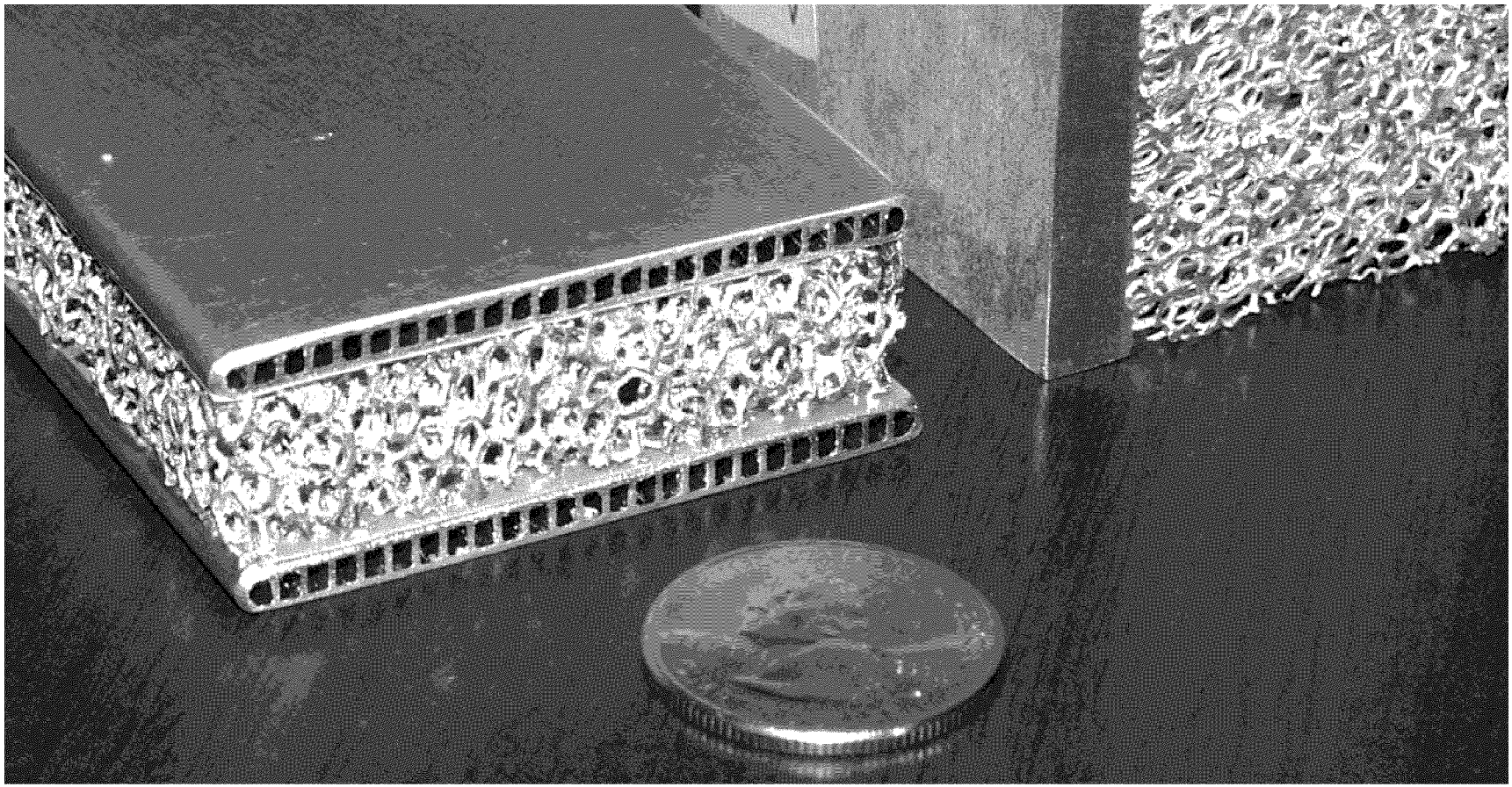
E-2C Interior



Foam Metal Heat Exchanger Basic Concept



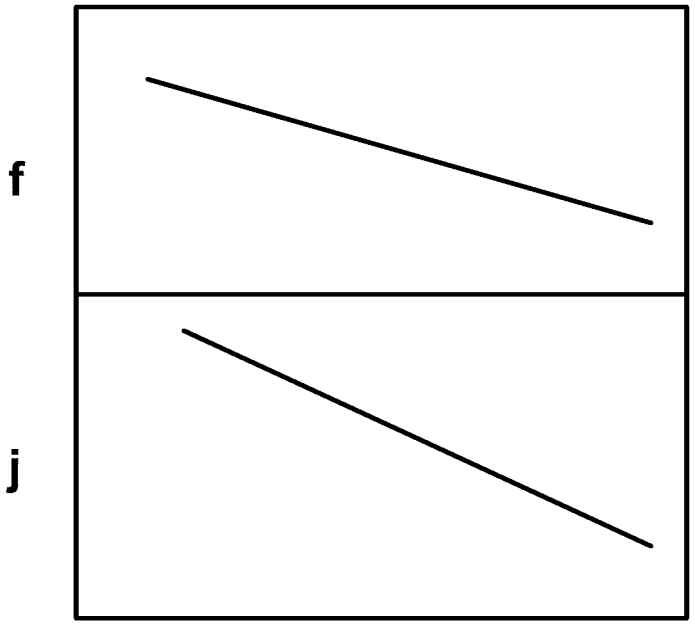
Manufacturing Demo Samples (ERG)



Data requirements

- Heat transfer and pressure drop vs Reynolds Number
  - Compressed Foams
  - Heff, ie $\eta\, h_{true}\, A_{es}$
  - $\Delta P/L$
  - Present In preferred Kays & London (K&L) Heat Transfer Data Format
    - Ref: Compact Heat Exchangers, Kays & London

Kays & London Data Presentation



Friction factor

$$f = \frac{\Delta p}{4\left(\frac{L}{D_h}\right)\left(\frac{\rho V^2}{2}\right)}$$

Colburn j factor

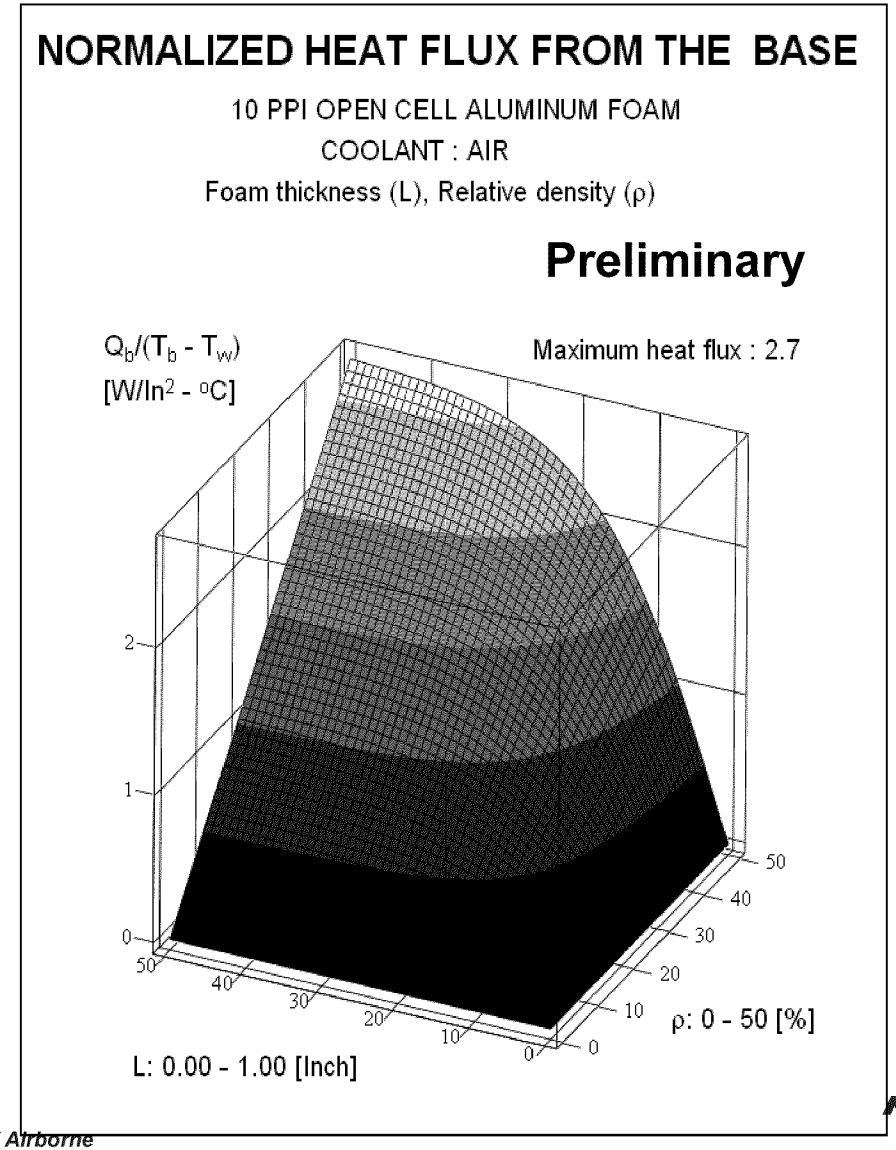
$$j = \frac{h}{\rho c_p V} P_r^{2/3}$$

$$= St * Pr^{2/3}$$

Definition of Terms

- Flow velocity
  - V= mass flow rate /(ρ A_{min}) , where A_{min} is the minimum flow area.
  - matrices G =ρV=W/(pA_{fr})
- Hydraulic diameter:
- D_h = 4 x (minimum flow area) / (total heat transfer area)
- L = flow length of heat exchanger
- R_e = ρ V D_h / μ

Projected Heff 10 ppi foam-sea level

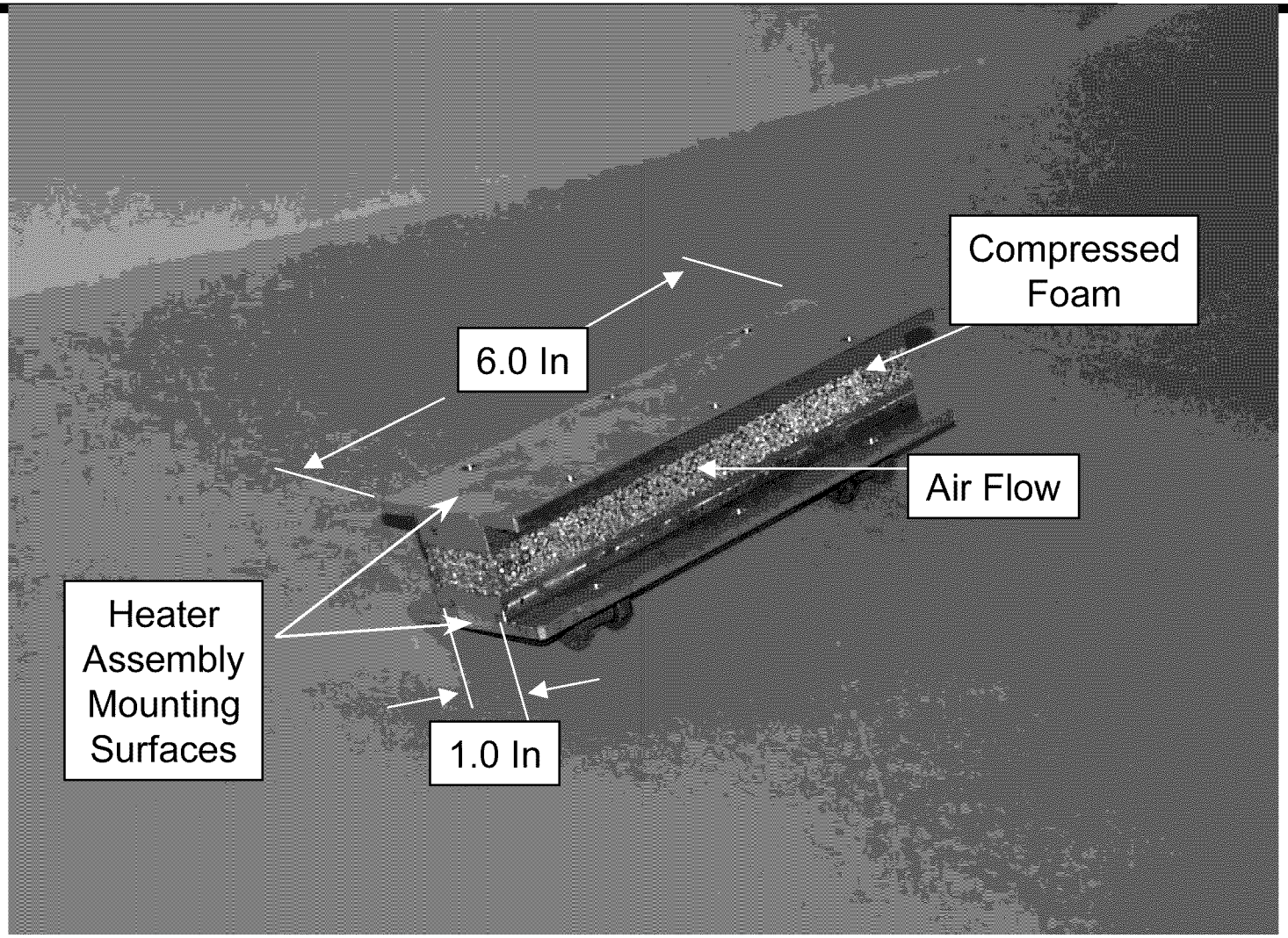


Heat Exchanger Design Methodology

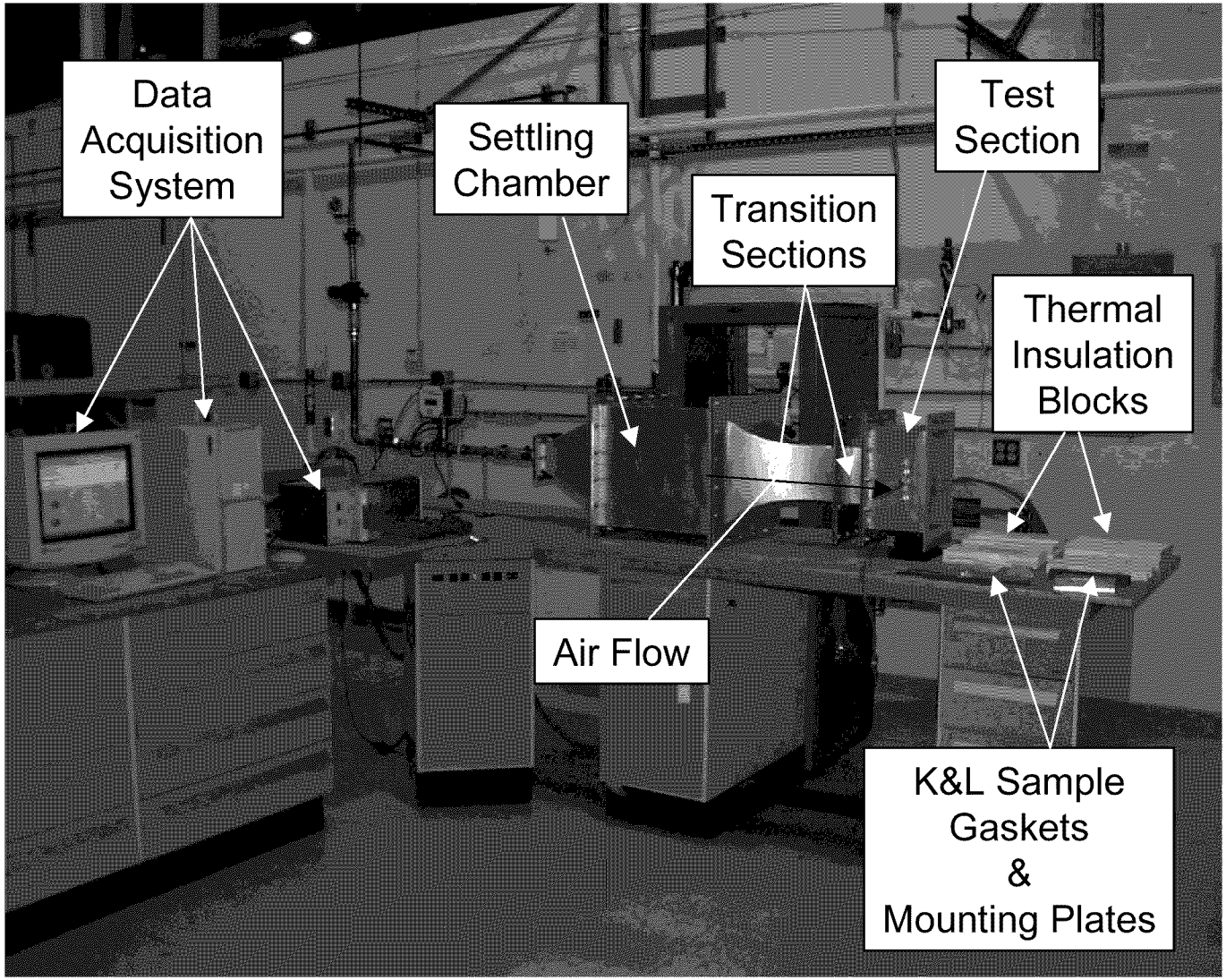
- Kays & London type measured data for extended surface
  - pressure drop vs. Re
  - heat transfer vs. Re
- Calculate h using K&L type data
- Apply same h to both extended surface and wall
- Calculate extended surface temperature effectiveness based on h, mat'l and geometry
- Calculate effective total heat exchange area

K&L Test Apparatus

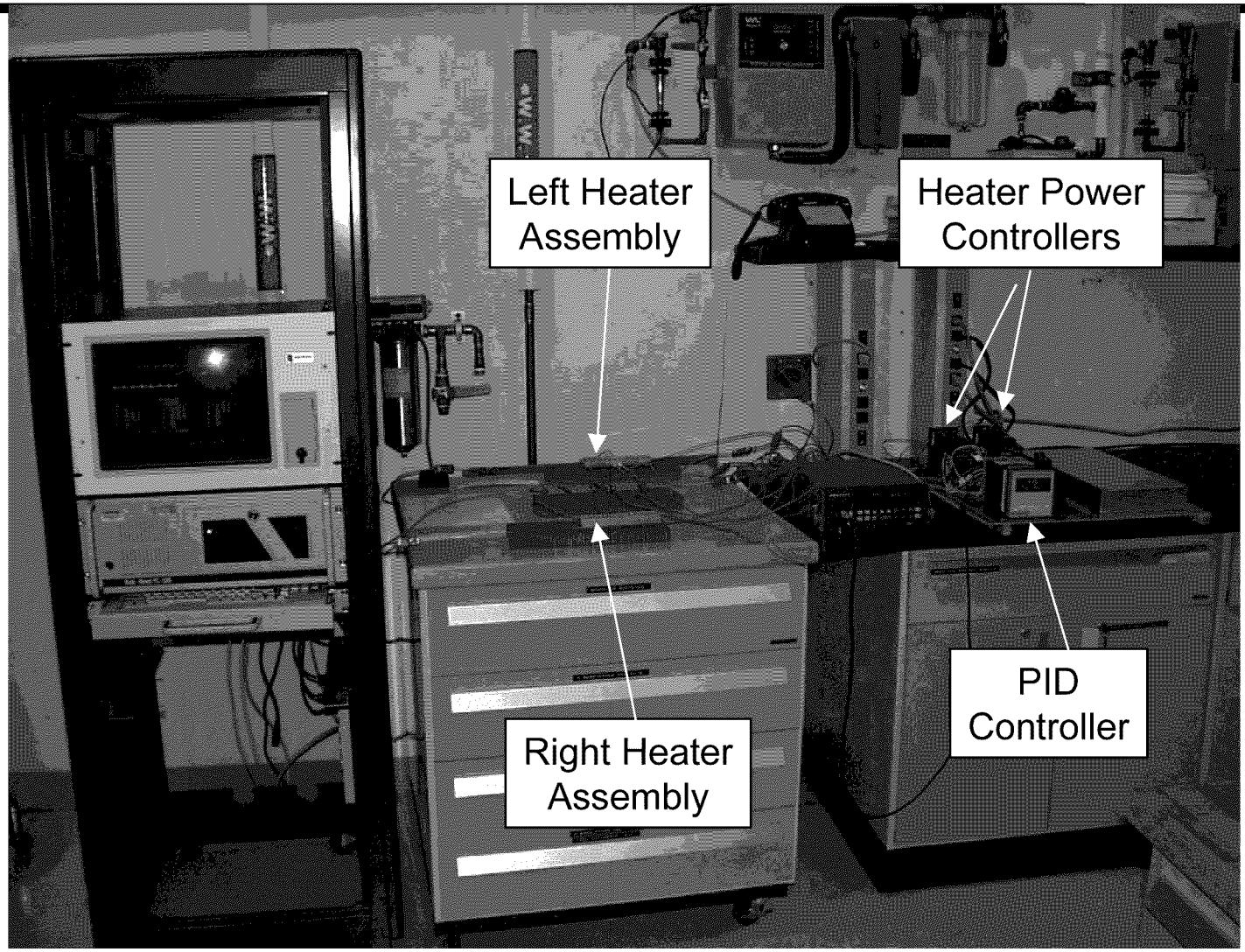
NGC KAYS & LONDON TEST SAMPLE



KAYS & LONDON TEST APPARATUS



K&L HEATER POWER PID CONTROL TEST



Summary - Technical Status / Direction

- E-2C LCS heat exchanger
  - Completed
    - LCS HX conceptual design
    - LCS HX initial sizing
    - K&L test apparatus design, fabrication, checkout
    - data acquisition system
    - temperature controller testing
    - air flow supply checkout
    - Instrument calibration
    - NGC K&L testing start 1-2 weeks
    - Foam metal HX sub element fabrication demo
    - Design system integration methodology

Summary - Technical Status / Direction (cont.)

- E-2C LCS work in progress
  - K&L sample testing
  - HX element fabrication demonstration
  - HX element thermal performance demonstration
  - Design system integration method verification
- E2C Integrated avionics racks
  - preliminary concepts
- Structurally integrated heat exchangers
  - preliminary concepts
- Additional specific aircraft applications